Coastal Ocean Optical Modeling: Integrating Optical Processes and Hydrodynamic Simulations of Sediment Resuspension and Transport-Phase 2

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LONG-TERM GOALS

The overall goals for this project are to develop robust, reliable, and portable mechanistically based models and algorithms for ocean optics. I am expanding on the parameterizations of Case 1 optical models for Case 2 coastal waters. The base parameterization involves chlorophyll concentration and the concentration and size distribution of suspended mineral matter. This brings in mineral optical cross sections, virtually unknown in coastal ocean optics.

OBJECTIVES

My efforts are to generate a valid, predictive, and portable Case 2 coastal ocean optical model. I am filling the hiatus in our knowledge of the optical effects of suspended and resuspended particulate mineral matter.

APPROACH

The Coastal Ocean Biogeo-optical Model that I have been developing is coming to fruition. The discovery that chlorophyll parameterizations of the Open Ocean Bio-optical Model (Weidemann et al, 1995) were adequate to predict the absorption coefficient in coastal regions (Stavn et al, 1998) was the stimulus for this development. The chlorophyll parameterization is not adequate to predict the total scattering coefficient in coastal regions, however - something must be added to make a Coastal Ocean Biogeo-optical Model: minimally the concentration of suspended mineral matter. In the near shore region The Littoral Sediment Optical Model (LSOM) of Dr. Timothy R. Keen will often be adequate to supply the missing information for the model. What is required is the size distribution of the bottom sediments and local data on tides, wind stress, and wave heights plus bottom currents from acoustic Doppler current profiler surveys or 2D fields derived from the Princeton Ocean Model.

I am presently supplying the missing information on suspended mineral matter in coastal waters by joint efforts with the Naval Research Laboratory (NRL), the Louisiana Universities Marine Consortium (LUMCON) - the University of Louisiana at Lafayette (ULL), and the University of

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14. ABSTRACT
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Southern Mississippi (USM). This involves collecting and filtering water samples, drying the filtered material, weighing it, ashing it, and weighing it again. This gives information on the concentration of Total Suspended Solids (TSS), Particulate Organic Matter (POM), and Particulate Inorganic Matter (PIM). I am doing preliminary elemental ratios on the ashed samples with Dr. Tyrone Daulton of the Marine Geosciences Division of the NRL. I am working with Dr. Rick Gould of the NRL on mineral/organic ratios and particle distributions. I am also working with Dr. Hans Rick of ULL on particle size distributions. In addition I am doing mineral/organic ratios with Mr. Kevin Mahoney of USM. Preliminary samples taken at LEO-15 during the field exercise of July, 2000 were apparently lost by Rutgers University. Thus I have been using data collected from the USM participation in the Northern Gulf Littoral Initiative cruises and I have been working up samples taken during the May 2002 Hyperspectral cruise of the Naval Research Laboratory.

With information on coastal inherent optical properties (absorption and scattering), I simulate the solution of the radiative transfer equation by Monte Carlo methods on the IBM SP at the North Carolina Super Computing Center. My graduate student, William Mulberry, is working this up.

WORK COMPLETED

The first direct determination of the suspended mineral optical scattering cross section has been done for the suspended mineral samples collected on the R/V Ocean Color cruises of the Hyperspectral cruise of the NRL performed at Mobile Bay, AL in May 2002. Initial analysis of the suspended mineral samples I had prepared was performed by Dr. Tyrone Daulton in August 2002. Field data have not yet been submitted to a national archive.

RESULTS

During the cruises of the R/V Ocean Color and the R/V Pelican, from a transect in Mobile Bay out to the near shore portion of the Gulf of Mexico, water samples were collected and analyzed extensively by many investigators. My analyses were of TSS, POM, and PIM. Along with the water samples concurrent optical data from the AC-9 meter and the Hydroscat were collected. The AC-9 data from the Pelican cruise and the Hydroscat are being processed and analyzed. The AC-9 data on total scattering and absorption from the Ocean Color cruise were available. I performed a multiple regression on the spectral scattering coefficients and the concentrations of PIM and POM. This multiple regression yielded the first directly determined suspended mineral scattering cross sections, Table 1., utilizing mineral mass concentrations and the particle scattering coefficient that we know about (Stavn et al., 2002). Previous attempts to determine optical scattering cross sections of suspended minerals required clever manipulations of multiparameter models of the scattering effects of various kinds of suspended and absorbing matter on remote sensing reflectance (Bukata, et al. 1995). The magnitude and decrease of the cross section with wavelength agree with Bukata et al.'s results but the small size of the database allows error coefficients that are great enough to mask the apparent trend with wavelength. The suspended mineral matter exerted the strongest control on the particle scattering coefficient $b_p(\lambda)$ while the effect of the suspended organic matter was not linear and the mass of suspended organic matter was a much less efficient predictor of the particle scattering coefficient,

Table 1. Spectral Optical Scattering Cross Sections (m2/g) for Suspended Mineral Matter. Mobile Bay, May 2002

$b^*_{pm}(412)$	$b^*_{pm}(440)$	$b^*_{pm}(488)$	$b^*_{pm}(510)$	$b^*_{pm}(532)$
0.60 ±0.12	**0.59 ±0.12**	**0.56 ±0.11**	**0.55 ±0.11**	**0.53 ±0.10**
$b^*_{pm}(555)$	$b^*_{pm}(650)$	$b^*_{pm}(676)$	$b^*_{pm}(715)$	
0.52 ±0.10	**0.38 ±0.12**	**0.44 ±0.08**	**0.42 ±0.08**	

Figure 1. Thus, to determine the organic particle scattering of Mobile Bay I took the difference of the total particle scattering coefficient and the mineral particle scattering coefficient determined from the mass of suspended mineral particles and the scattering cross section of Table 1. I then compared

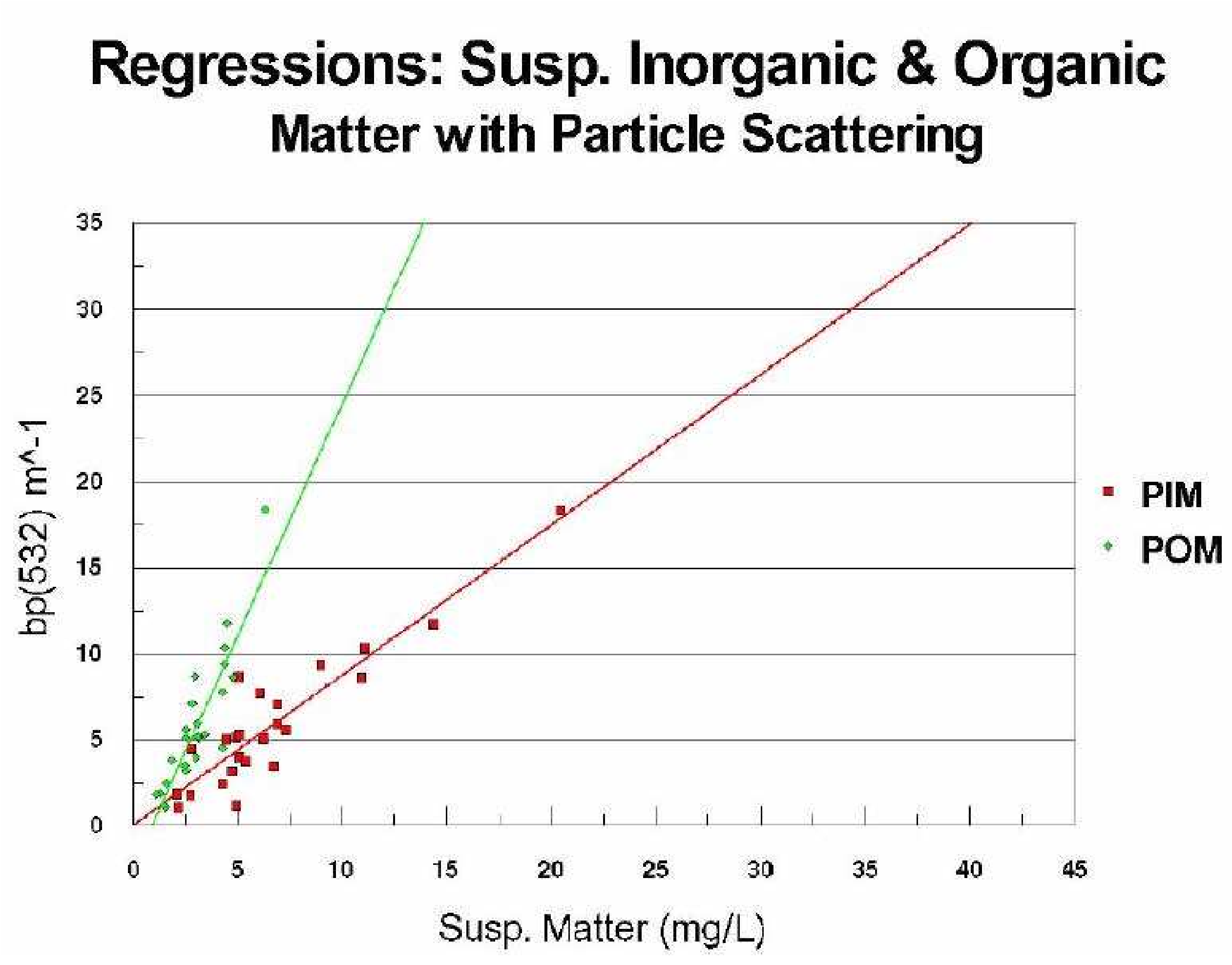

Figure 1. Regressions of mass of PIM and POM on particle scattering coefficient at 532 nm. PIM is not well correlated with the particle scattering coefficient, Mobile Bay, Alabama, May 2002.

the organic particle scattering coefficient from Mobile Bay with the organic particle scattering coefficient from the chlorophyll relation proposed by Loisel and Morel (1998). The comparison was made at one wavelength (532 nm) which was typical of the relation at other wavelengths and the results reported in Table 2. We see that, although Case 1 algorithms can produce a good estimate of the absorption coefficient in the Case 2 hydrosol, exclusive of that due to yellow substance, (Stavn et al, 1998) the Case 1 particle scattering algorithms based on chlorophyll concentration will be efficient for offshore coastal waters. However, such algorithms become less effective as we approach the coastline and encounter more suspended mineral matter.

Table 2. Comparison of Organic Particle Scatter Coefficient from Multiple Regression and Organic Particle Scatter Coefficient from Chlorophyll. Mobile Bay, May 2002

$b_{po}(532)$ Low Suspended Matter Station	$b_{po}(532)$ Medium Suspended Matter Station	$b_{po}(532)$ High Suspended Matter Station
0.34 m^{-1}	**3.02** m^{-1}	**4.63** m^{-1}
Loisel & Morel	Loisel & Morel	Loisel & Morel
0.31 m^{-1}	**1.58** m^{-1}	**1.89** m^{-1}

In summary, the key to constructing adequate Case 2 optical models is knowledge of the suspended mineral matter. The scattering due to organic matter comes from allochthonous and autochthonous sources that are not yet well understood. The suspended mineral matter dominates the particle scattering in coastal waters and is the major source of the remote sensing signal.

IMPACT/APPLICATIONS

The database I am building up on suspended mineral and organic concentrations and particle scattering will allow accurate inversions of the remote sensing signal for concentrations of all suspended matter in Case 2 waters. More work needs to be done on obtaining knowledge of mineral concentration and the nature of the suspended minerals to allow valid algorithms that are not regionally limited as is the case at present.

TRANSITIONS

The Ocean Optics section of the Oceanography Division of the NRL is applying these results to remote sensing algorithms for increased accuracy and portability (Gould et al., 2002). I am currently working with Dr. Johannes Rick, Biology Dept., ULL to apply the mineral organic ratios of the Mobile Bay exercise to his particle size distributions collected during that exercise.

RELATED PROJECTS

Herewith I list the projects being pursued concurrently with the Littoral Optical Environment initiative of the Naval Research Laboratory and the Office of Naval Research.

1 - Timothy R. Keen, Ocean Dynamics and Prediction Branch (Code 7320), NRL, Stennis Space Center, MS is working closely with me in extending these results to fine-grained sediments for Great Bay, NJ (LEO-15), Hamlet's Cove, FL, and the Hyperspectral cruise of May, 2002.

2 - John Kindle, Coupled Dynamic Processes Section (Code 7331), NRL, Stennis Space Center, MS is interested in the optimal wavebands for a surface layer model of hydrodynamically forced primary productivity in the Arabian Sea. We have been discussing ways of incorporating minerogenic results.

3 - Vladimir I. Haltrin, Ocean Optics Section (Code 7333), NRL, Stennis Space Center, MS has been working with me on optimized codes for Mie Scattering calculations and on scattering properties of small clay particulates and small quartz-like particles. The recent volume scattering functions from the Hyperspectral cruise are of great interest.

4 - Steven Lohrenz, University of Southern Mississippi. We are working on generating a database of optical scattering and mineral-organic concentrations for the Northern Gulf Littoral Initiative. There will be at least 6 research cruises to provide this database.

5 - Johannes Rick, Dept. of Biology, University of Louisiana, Lafayette is doing studies of the biogeochemistry and particle distributions of the region of the mouth of the Atchafalaya, LA and we are collaborating on the mineral/organic aspects of the particle distributions.

6 - Tyrone Daulton, Marine Geosciences Division, NRL has been looking at my mineral samples to determine elemental ratios utilizing x-ray analysis through the electron microscope. Further work on direct determination of refractive indices of these samples is planned.

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